Fishery Data Series No. 09-44

Sonar Estimation of Fall Chum Salmon Abundance in the Sheenjek River, 2008

by

Roger D. Dunbar

August 2009

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

Dual-Frequency Identification Sonar was used to estimate chum salmon, *Oncorhynchus keta* escapement in the Sheenjek River from August 9 to September 24, 2008. This was the fourth season that Dual-Frequency Identification Sonar was used to estimate chum salmon passage in the Sheenjek River. The sonar-estimated escapement through September 24 was 42,842 chum salmon. The estimate was subsequently expanded to a total abundance estimate of 50,353 using run time data from the Rampart tag recovery fish wheel. For comparison with past years, only the expanded right bank estimate of 42,206 was used to evaluate whether the biological escapement goal was obtained. The right bank estimate was 16% below the low end of the Sheenjek River biological escapement goal of 50,000 to 104,000 chum salmon. Median passage while the sonar was operating was observed on September 11. Peak single day passage was observed on September 20; when an estimated 2,319 fish passed the sonar site. A diel migration pattern showed most chum salmon passed the sonar site during periods of darkness or suppressed light. Range of ensonification was considered adequate for most fish which passed. The passage estimate should be considered conservative since it does not include fish migrating beyond the counting ranges or fish present before the sonar equipment was in operation. One hundred seventeen vertebrae samples were collected for age determination. Analysis of vertebrae showed age 0.4 fish dominated at 51.7%, age 0.3 fish represented 43.1%, age 0.5 about 3.5%, and age 0.2 and age 0.6 were both 0.9% of all fish sampled. Female chum salmon comprised 44% of the sample and 56% were male.

Key words: chum salmon, *Oncorhynchus keta,* DIDSON, sonar, hydroacoustics, escapement, enumeration, Yukon River, Porcupine River, Sheenjek River

INTRODUCTION

Five species of anadromous Pacific salmon *Oncorhynchus* are found in the Yukon River drainage. However, chum salmon *O. keta* are the most abundant and occur in genetically distinct summer and fall runs (Seeb et al. 1995; Wilmot et al. 1992). Fall chum salmon are larger, spawn later, and are less abundant than summer chum salmon. Spawning occurs in upper portions of the drainage in spring-fed streams, which usually remain ice-free during the winter (Buklis and Barton 1984). Major fall chum salmon spawning areas occur within the Tanana, Chandalar, and Porcupine River systems, as well as portions of the upper Yukon River in Canada (Figure 1). The Sheenjek River (66° 47.02 N 144° 27.82 W) is one of the most important producers of fall chum salmon in the Yukon River drainage. Located above the Arctic Circle, it heads in glacial ice fields of the Romanzof Mountains, a northern extension of the Brooks Range, and flows southward approximately 400 km to its terminus on the Porcupine River (Figure 2).

INRIVER FISHERIES

Fall chum salmon are harvested for commercial and subsistence uses. Commercial harvest is permitted along the entire Yukon River in Alaska and in the lower portion of the Tanana River. No commercial harvest is permitted in any other tributaries of the drainage including the Koyukuk and Porcupine River systems. Although commercial harvest occurs in the Canadian portion of the Yukon River near Dawson, most fish are taken commercially in the lower river, downstream of the village of Anvik. Subsistence use of fall chum salmon is greatest throughout the upper river drainage, upstream of the village of Koyukuk.

Although the Alaskan commercial fishery for Yukon River fall chum salmon developed in the early 1960s, annual harvests remained relatively low through the mid 1970s. Estimated total inriver utilization (U.S. and Canada commercial and subsistence) of Yukon River fall chum salmon was below 300,000 fish per year before the mid 1970s (JTC 2009). Inriver commercial fisheries became more fully developed during the late 1970s and early 1980s. Harvest peaked in

1981 at 677,257 fish (Appendix A1). In the mid 1980s, management strategies were implemented to reduce commercial exploitation on fall chum stocks and to improve low escapements observed throughout the drainage during the early 1980s. In 1987, the commercial fall chum fishery was closed in the Alaskan portion of the drainage. In 1992, commercial fishing was restricted to a portion of the Tanana River during the fall season. In addition to a commercial fishery closure, 1993 marked the first year in state history that Alaska Department of Fish and Game (ADF&G) instituted a total closure of subsistence fishing in the Yukon River. The closure was in effect during the latter portion of the fall season in response to the extremely weak fall chum salmon run.

Yukon River fall chum salmon runs improved somewhat between 1994 and 1996. In 1994, limited commercial fishing was permitted in the Alaskan portion of the upper Yukon River, and in the Tanana River. Commercial fishing was permitted in all districts throughout the Alaska portion of the drainage in 1995. In 1996, limited commercial fishing was permitted in selected districts of the mainstem Yukon River and no commercial fishing was permitted in the Tanana River. Poor salmon runs to Western Alaska between 1997 and 2003 resulted in partial or total closures to commercial and subsistence fishing in Alaskan and Canadian portions of the drainage during those years. Commercial fishing was only permitted in the Tanana River and Canada in 1997. A total commercial fishery closure and limited subsistence fishing was required in 1998. Limited commercial harvest was permitted in 1999, and a total commercial fishery closure and severe subsistence fishing restrictions were required in 2000, 2001, and 2002. Limited commercial fishing for fall chum was allowed from 2003 through 2008. Subsistence harvest of fall chum in 2003 was also limited while the subsistence harvest in 2004 was unrestricted except within the Canadian portion of the Porcupine River. There were no restrictions on subsistence harvest from 2005 through 2008.

ESCAPEMENT ASSESSMENT

Between 1960 and 1980, some portions of Yukon River fall chum salmon runs were estimated from mark–recapture studies (Buklis and Barton 1984). Aside from these tagging studies, and aerial assessment of selected tributaries that have been conducted since the early 1970s, comprehensive escapement estimation studies were sporadic and limited to only 2 streams: the Delta River (Tanana River drainage) and the Fishing Branch River (Porcupine River drainage). In the early 1980s, comprehensive escapement assessment studies intensified on major spawning tributaries throughout the drainage.

The Sheenjek River is one of the most intensely monitored fall chum salmon spawning streams in Yukon River drainage. Escapement observations date back to 1960 when USFWS (U.S. Fish and Wildlife Service) reported chum salmon spawning in September. Between 1974 and 1981, escapement observations in the Sheenjek River were limited to aerial surveys flown in late September and early October (Barton 1984). Beginning in 1981, escapements were monitored using Bendix[1] fixed location, single beam, side looking sonar systems (Dunbar 2004). However, an early segment of the fall chum salmon run was not measured prior to 1991 because the project typically started around August 25, after that portion of the run had passed. Beginning in 1991, to include the early segment of the run, the project startup was changed to start about 2 weeks earlier. The sonar-estimated escapements for 1986 through 1990 have been expanded to include

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

estimated early fish passage (Barton 1995). Termination of sonar counting was consistent between 1981 and 2007, averaging September 24, except in 2000 when the project was terminated early because of extremely low water (Barton 2002).

The Sheenjek River sonar project has estimated fall chum salmon escapement since 1981 while undergoing a number of changes in recent years. The project originally operated Bendix single-beam sonar equipment and, although the Bendix sonar functioned well, the manufacturer ceased production in the mid 1990s and no longer supports the system. In 2000, ADF&G purchased a Hydroacoustic Technology, Incorporated (HTI) model 241 split-beam echosounder for use on the Sheenjek River. In 2000 and 2002, the new split-beam system was deployed alongside the existing single-beam sonar and produced comparable results (Dunbar 2004). In 2003 and 2004, the split-beam sonar system was used exclusively to enumerate chum salmon in the Sheenjek River.

Historically, because of unfavorable conditions for transducer placement on the left bank[2], only the right bank of the Sheenjek River has been used to estimate fish passage, except for 1985 through 1987 when single-beam sonar was tested on the left bank. Drift gillnet studies in the early 1980s suggested that distribution of the migrant chum salmon was primarily concentrated on the right bank of the river at the current sonar site, with a small but unknown proportion passing on the left bank (Barton 1985). In 2002, ADF&G began experimenting with a new Dual Frequency Identification Sonar (DIDSON), manufactured by Sound Metrics Corporation, for counting salmon in small rivers. This system appeared to be more accurate, easy to use, with the ability to operate across substrate profiles unacceptable for single-beam or split-beam systems (Maxwell and Gove 2004). The uneven substrate on left bank of the Sheenjek River was selected as an ideal candidate for experimenting with this system. In 2003, a DIDSON was deployed on the previously unmonitored left bank. Using DIDSON data, it was estimated that approximately 33% of the fish were migrating up the left bank (Dunbar 2006). Given this surprisingly large number, it was proposed that DIDSON be deployed on both banks in the future. In 2004 and 2005, DIDSON and HTI split-beam sonar were deployed side-by-side on the right bank and found that DIDSON estimates were 20% higher than the split-beam estimates (Dunbar 2009). Since 2005, only DIDSON has been the deployed to estimate chum salmon escapement on both banks of the Sheenjek River.

Escapement estimates averaged 102,042 from 1981–2007 and 172,735 during the most recent 5-year period of 2003–2007 (Table 1). This increase in the average escapement over the last 5 years can be attributed to the extraordinary large run (561,863 fall chum salmon) in 2005. From 1992 through 2000, the Sheenjek River biological escapement goal (BEG) was set at 64,000 fall chum salmon. This goal was based upon aerial survey and hydroacoustic data collected between 1974 and 1990 (Buklis 1993). In 2001, the department completed a review of the escapement goals for Yukon River fall chum stocks, including the Sheenjek River. Based on this review of long term escapement, catch, and age composition data, the BEG for the Sheenjek River was given a range of 50,000 to 104,000 fall chum salmon (Figure 3) (Eggers 2001).

STUDY AREA

This project site is located approximately 10 km upstream from the mouth of the Sheenjek River (Figure 2). While created by glaciers, the Sheenjek River has numerous clearwater tributaries.

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[2] Left and right bank refers to the bank on the left or right side of the river when looking downstream.

Water clarity in the lower river is somewhat unpredictable, but generally clearest during periods of low water. Historically, the water level begins to drop in late August or early September. Upwelling ground water composes a significant portion of the river flow volume, especially in winter. It is in these spring areas that fall chum salmon spawn, particularly within the lower 160 km.

OBJECTIVES

Objectives for the 2008 Sheenjek River sonar project were to:

- Estimate daily and seasonal passage of chum salmon escapement using fixed, side looking DIDSON systems.
- Collect a minimum of 30-35 vertebrae samples per week, up to 180 for the season, to estimate age and sex composition of the spawning chum salmon population, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 (α=0.05 and d=0.10).
- Collect selected climate and hydrologic data daily at the project site.

METHODS

HYDROACOUSTIC EQUIPMENT

DIDSON units were deployed on August 9 on the right and left banks of the Sheenjek River at the historic sonar site (Figures 4 and 5). The right bank DIDSON (long range) operated at 1.2 MHz, its high frequency option, and the left bank DIDSON (standard) was operated at 1.1 MHz, its low frequency option. Both the low and high frequency modes have a viewing angle of 29° in the horizontal axis, and 14° in the vertical axis. Both DIDSON units were mounted on an H-shaped stand equipped with a manual crank-style rotator to facilitate aiming (Figure 6). A 152 m cable carried power and data between the DIDSON units in the water and the topside breakout boxes. A wireless router was used to transfer data between the left bank breakout box and a laptop computer on the right bank. All surface electronics were housed in a small self-supporting tent on the left bank and a 10x12 wall tent on the right bank. All electronics were powered with two portable 1000 W generators (one on each bank) run continuously. Sampling was accomplished with DIDSON software running on laptop computers. After establishing the parameters that maximize sonar effectiveness, both left and right bank systems were left to operate 24 hours per day. Sonar data was collected in twenty four 60-minute digital samples per bank and day by the DIDSON data acquisition software. Files were transferred to, and stored on, an external hard drive enclosure, configured for RAID 1 data storage. Files were later examined and edited by the field crew to produce an estimate of fish passage. The crew, consisting of 2 technicians, monitored the sonar and interpreted the data during 6 to 7 hour shifts twice daily.

SITE SELECTION AND TRANSDUCER DEPLOYMENT

The gently-sloping river bottom and small cobble at the historic right bank counting location, and the silty cut bank directly across the river, were adequate for ensonification. A bottom profile was obtained after initial transducer placement at the counting location by stretching a rope across the river and measuring water depth at one meter increments with a calibrated pole. The transducers and manual crank style rotators were mounted on stands made of aluminum pipe and deployed from each bank. The stands were designed to permit raising and lowering of the transducers by sliding them up or down along 2 riser pipes that extended above the water and was secured in place with sandbags. Technicians adjusted the aim by viewing the video image and relaying aiming instructions to a technician at the transducers stand via handheld VHF radio. The transducers were deployed in water ranging from 0.5 m to 1.0 m in depth, and aimed perpendicular to the current along the natural substrate. An attempt was made to ensure the transducers were deployed at locations where there was sufficient current, i.e., areas without eddies or slack water where fish milling behavior can occur.

Technicians used an artificial acoustic target during deployment to ensure transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beams. The target, an airtight 250 ml weighted plastic bottle, was allowed to drift downstream along the river bottom and through the acoustic beams. Drifts were made at multiple ranges in order to verify target detection at all ranges of interest. Beam aim adjustment and target drifts were repeated until a satisfactory result was achieved.

A fish lead was constructed shoreward from the transducer on the right bank to prevent upstream salmon passage inshore of the transducer. The fish lead was constructed of 5 cm by 5 cm by 1.2 m high galvanized chain-link fencing attached to 2.5 m metal "T" stakes. The lead was positioned to guide fish beyond the nearfield of the sonar transducer. Whenever a transducer was relocated because of rising or falling water level, the beam was re-aimed to ensure proper ensonification, and the lead was repositioned as appropriate. Installation of a fish lead on the left bank was prevented due to deep water and floating debris close to shore. This transducer was placed very close to shore, and natural diversions such as submerged debris and fallen clumps of riverbank were relied on to keep the salmon from passing behind or to close to the transducer.

SONAR COUNT ADJUSTMENTS

Data collected by the DIDSON were transferred to another computer for counting and editing using DIDSON editing software. Upstream migrating fish were counted by marking each fish track on the DIDSON echogram (Figure 7). Upstream direction of travel was verified using the DIDSON video feature. Counts were saved as text files and recorded on a count form. Brief interruptions in sampling intermittently occurred when routine maintenance (i.e. silt removal) or relocation of the transducers was required.

Whenever a portion of a sample was missing, passage was estimated by expansion based on the known portion of the sample. The number of minutes in a complete sample was divided by the known number of minutes counted and then multiplied by the number of fish counted in that period. Passage was estimated as:

$$\hat{y}_i = \left(60 / m_c\right) x_i \qquad (1)$$

Where 60 is the number of minutes in a complete sample, m_c is the number of minutes in sample that were actually counted, and x_i is the count for each sample i.

If data from one or more complete samples was missing, passage for the missing sample(s) was interpolated by averaging counts from the sample immediately before and after the missing sample(s):

$$\hat{y}_i = \frac{x_a + x_p}{2} \qquad (2)$$

Where i is the ith missing value, x_a is the count of the sample after the missing sample(s), and x_p is the count of the sample prior to the missing sample(s).

Counts caused by fish other than salmon were assumed insignificant based upon historic visual "tower" observations and test fishing records collected at the site. After editing was complete, an estimate of daily and cumulative fish passage was produced and forwarded to the Fairbanks ADF&G office via satellite telephone. The estimates produced during the field season were further scrutinized post season and adjusted as necessary.

TEMPORAL AND SPATIAL DISTRIBUTIONS

Fish range distributions were examined postseason by importing text files containing all fish track information into *R* (R Development Core Team 2007) where the fish counts were binned by range. Microsoft® *Excel* was used to plot the binned data and investigate the spatial distribution of fish passing the sonar site. Histograms of passage by hour were also created in Microsoft® *Excel* to investigate diel patterns of migration.

TEST FISHING AND SALMON SAMPLING

Region-wide standards have been set for the sample size needed to describe the age composition of a salmon population. These standards apply to the period or stratum in which the sample is collected. These goals are based on a one in ten chance (precision) of not having the true age proportion (p_i) within the interval $p_i \pm 0.05$ for all i ages (accuracy).

The preferred method of aging Yukon River fall chum salmon, when in close proximity to their natal streams, is from vertebrae collections (Clark 1986[3]). As described in Bromaghin (1993), a sample size of 150 chum salmon is needed, assuming 2 major age classes with minor ages pooled, and no unreadable vertebrae. Allowing for 20% unreadable vertebrae, the Sheenjek River sample size goal was set at 30 chum salmon per week up to a maximum of 180 for the season.

A beach seine was periodically fished at the sonar site to collect adult salmon for age and sex composition. The beach seine (3-inch stretch measure) was 30 m in length by 55 meshes deep (~3 m). Chum salmon were collected with the beach seine, enumerated by sex using external characteristics, and measured to the nearest 5 mm, from mid-eye to tail fork (METF). Additionally, 3 vertebrae were taken from each fish for age determination.

CLIMATE AND HYDROLOGIC OBSERVATIONS

A water level gauge was installed at the sonar site and monitored daily, with readings made to the nearest centimeter. Surface water temperature was measured approximately 30 cm below the surface daily, with a HOBO U22 water temperature data logger, or a pocket thermometer. The data logger was suspended from a float tied to the water level gauge and set to record 6 times a day. Minimum and maximum air temperatures, and wind velocity and direction were measured daily with a Weather Wizard III weather station. Other daily observations included occurrence of precipitation and percent cloud cover. Climate and hydrologic observations were recorded at approximately 1800 hours daily.

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[3] Clark, R. A. 1986. Sources of variability in three ageing structures for Yukon River fall chum salmon (*Oncorhynchus keta Walbaum*) escapement samples. Alaska Department of Fish and Game, Division of Sport Fish, (Region III unpublished report), Fairbanks.

RESULTS

RIVER AND SONAR COUNTING CONDITIONS

In 2008, the right bank transducer was deployed approximately in the same location on the point bar that has been used in recent years, while the cutbank directly across the river continued to work well for the other transducer. On August 14 the river bottom at the counting location dropped abruptly from the left bank at a rate of 32 cm/m (bottom slope ≈ 17.6°) to the thalweg approximately 12 m from shore, and then sloped gently up toward the right-bank point bar at a rate of approximately 7 cm/m (bottom slope ≈ 4.0°) (Figure 8). River width measured 66 m, and much of the nearshore zone along the left cutbank was cluttered with fallen trees and other woody vegetation, while the right bank consisted of small cobble with no debris.

The water level was moderately high upon arrival at the project site in 2008. With respect to the initial reading of the water gauge upon deployment on August 9, the water level climbed 5 cm during the first day, and then steadily dropped the remainder of the season to 128 cm below the initial reading by September 24 (Figure 9, Appendix B1). The water level climbed 2 cm the final 2 days of observation. Water temperature at the project site ranged from 3.0°C to 12.1°C, and averaged 7.4°C.

Fluctuations in water level affected placement of the transducers with respect to shore. As the water level dropped, the transducers were moved out. With installation of sonar on both banks, efforts were made to insure that the counting ranges of each DIDSON did not overlap. While no attempt was made to estimate fish passage beyond the counting range, occasional expansions or interpolations of sonar counts were made to estimate fish passage for periods when data was missing because of system failures or moving the transducers.

ABUNDANCE ESTIMATION

The 2008 sonar-estimated escapement was 42,842 fall chum salmon for the 47-day period from August 9 through September 24 (Table 2). Table 3 shows the amount of time by day that either expansion or interpolation was used to calculate hourly or daily passage estimates. Daily passage estimates were relayed to the fishery managers in Fairbanks every morning via satellite telephone.

When sonar operations ceased on September 24 there was relatively high (1,664 fish per day) passage at the project site. Projects downriver experienced passage of relatively large numbers of fall chum salmon that would not have reached the sonar site by the time the project terminated, and many salmon were visually observed in the Sheenjek and Porcupine rivers when boating back to Circle at the end of the season. Given these circumstances, the sonar-estimated escapement was expanded to 50,353 to account for chum salmon that were most likely not counted after termination of the project (Table 1) (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication). The expansion was calculated by using a second order polynomial equation calculated to October 9 (correlated to run timing at Rampart Rapids test fish project). The resulting equation for determining the chum salmon passage for each day expanded for after sonar operations ceased was:

$$y_i = \frac{L}{d^2}\left(x_i - d\right)^2 \tag{3}$$

Where y_i is the ith daily passage estimate, L is the count on the last day, d is the total number of days expanding for, and x_i is the day number being estimated (where i = 1 through 15). Table 4 shows resulting daily counts from September 25 through October 9.

TEMPORAL AND SPATIAL DISTRIBUTION

Chum salmon were present in the river when right bank sonar counting was initiated on August 9, as evidenced by the 96 fish estimated passing that day. The largest passage estimate of 2,319 fish occurred on September 20 (Table 2 and Figure 10). An estimated 1,664 chum salmon passed the project site on September 24, the final day of sonar operation.

The diel pattern of migration of Sheenjek River chum salmon typically observed in most years (Dunbar 2004) was observed again in 2008 (Figure 11). Upstream migration was heaviest in periods of darkness or suppressed light, with fish moving in greater numbers close to shore. This pattern was most prevalent on the right bank. Average fish passage between 1900 and 0700 the following day was 70 %, while between 0700 and 1900, 30 % of the fish passed. The period of minimal passage was 1300 hours, while the highest average passage occurred at 2100 hours.

During the fall chum salmon run, 16% of migrating salmon passed on the left bank and 84% passed on the right bank (Figure 10). The highest proportional passage on the left bank occurred on August 12 (70%), while the lowest occurred on September 17 (5%). Most migrating chum salmon were shore-oriented, passing through the nearshore portion of the acoustic beam. On the right bank, approximately 69% of the fish counted were passing through the first 10 m of the counting range (Figure 8). The first few meters had fewer fish due to the placement of the fish lead in relation to the transducer. On the left bank, 99% of the fish were detected within 9 m of the transducer. The distribution of fish on the left bank was farther offshore because of clumps of sod and bushes that had sloughed off of the bank just downstream of the transducer.

AGE AND SEX COMPOSITION

In 2008, a total of 117 chum salmon (66 males; 51 females) were collected for sampling (Table 5). There were 64 seine hauls made at the sonar site, river kilometer (rkm) 10, and 15 seine hauls were made at rkm 9 from September 2 through September 22. One hundred sixteen vertebrae samples collected were readable. From these 116 samples it was determined that age 0.4 predominated (51.7%), the proportion of age 0.3 fish observed was 43.1%, age 0.5 about 3.5%, and age 0.2 and age 0.6 were both 0.9% (Mike Parker, Commercial Fisheries Biologist, ADF&G, Fairbanks, unpublished memorandum 23 January 2009) (Appendix C1).

DISCUSSION

ESCAPEMENT ESTIMATE

This was the fourth season that DIDSON was used to estimate fall chum salmon passage in the Sheenjek River, and the fourth season since 1987 that both banks have been fully monitored. The DIDSON systems performed well on both right and left banks over the entire season with no major technical difficulties or failures. The DIDSON, with its wide vertical beam angle (14°) was the ideal system for the previously unmonitored left bank, where the profile is steep and less linear than the right bank. Procedures used for counting DIDSON files worked well for estimating salmon passage at the site. All data files were processed in a reasonable amount of time. Factors affecting termination of sonar counting in 2008 included logistics associated with closing down camp, and impending winter weather.

Although sonar has been used to monitor chum salmon escapements in the Sheenjek River since 1981, project operational dates have only been consistent since 1991. Barton (1995) used run timing data from the nearby Chandalar River to expand Sheenjek River run size estimates for 1986–1988, and 1990 to a comparable time period (Table 1). The 1989 estimate was expanded using Sheenjek River aerial survey observations made before sonar operations in that year (Table 1). Barton (2002) used Sheenjek River run timing data from 1986 to 1999 to expand the estimated escapement for 2000, when sonar operations terminated early. Because of unusually high and increasing passage when the project terminated in 2003, the escapement estimate may not have reflected the actual amount of salmon escapement to the Sheenjek River. In order to assess whether the BEG was achieved, the escapement estimate was subsequently expanded using run timing data from the Rampart tag recovery fish wheel (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, unpublished memorandum 24 February 2004). The same scenario occurred in 2005 - with passage both high and increasing when operations ceased. With downriver projects reporting late runs, the escapement estimate was again expanded using run timing data from the Rampart tag recovery fish wheel (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication).

The 2008 sonar estimated escapement of 42,842 chum salmon, for the 47-day period August 9 through September 24, was expanded to 50,353 to account for chum salmon that may have passed after sonar operations ceased (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication). The expanded right bank estimate of 42,206 chum salmon was 16% below the low end of the BEG of 50,000 to 104,000 chum salmon. Since 1992 the right bank estimate has been used to asses the BEG because it was the only bank monitored. Until more data is collected, the right bank estimate will continue to be used for assessing the BEG. The fact that the DIDSON estimates may be 20% higher than split-beam estimates (Dunbar 2009) must also be taken into consideration when evaluating weather or not the BEG has been met. This low escapement was somewhat expected because the major parent year escapement levels were 44,047 in 2003 (returning age 0.4 fish) and 37,878 in 2004 (returning age 0.3 fish).

Drift gillnet studies conducted in the 1980s concluded that only a small proportion of the salmon pass on the left bank (Barton 1985). In 2003 preliminary work with the DIDSON on both banks at the sonar site indicated as many as 33% of the fish migrated on the left bank (Dunbar 2006). This season 16% of the fish migrated on the formerly unmonitored left bank, compared to 40% in 2007 and 39% in 2005 and 2006. Continued estimation of salmon passage on both banks should yield more accurate information on the total escapement to the Sheenjek River.

The 2008 season was characterized by average even-year fall chum salmon runs to most Yukon drainage river systems, with the Sheenjek and Porcupine rivers being exceptions. High numbers of returning fall chum salmon were reported in the nearby Chandalar River, where 162,000 chum salmon were estimated to have migrated past the sonar station during the 50 day period of August 8 through September 26 (JTC 2009). As with the Sheenjek estimate, the Chandalar estimate was expanded post season to 178,000 chum salmon to account for fish that most likely passed after sonar operations ceased (JTC 2009). The 2008 expanded estimated escapement in the Chandalar River was 17% above the upper end of the BEG range of 74,000 to 152,000 fall chum salmon. During the 33-day period of September 9 through October 11, 18,551 (subsequently expanded to 20,055) chum salmon passed the DFO weir on Fishing Branch River (JTC 2009). The 2008 Fishing Branch River escapement was slightly below the interim management escapement goal of 22,000 to 49,000 chum salmon. Above average numbers of returning fall chum salmon were reported in the Canadian portion of the mainstem Yukon River drainage. Most fall chum salmon escapement goals were achieved within the Yukon River drainage in 2008, and commercial fishing opportunity was high with moderate effort and subsistence opportunity was liberal.

ACKNOWLEDGMENTS

The author wishes to acknowledge the sonar field camp personnel, ADF&G technicians Susan Klock, and Chris Sewright for their dedication to the project, and collecting most of the data used in this report. Thanks to Malcolm McEwen, Bruce McIntosh, and Carl Pfisterer, for logistical support. Finally, I thank Bruce McIntosh, Toshihide Hamazaki, and Carl Pfisterer for their review and editorial comments on this manuscript.

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TABLES AND FIGURES

Table 1.–Operational dates, and escapement estimates of fall chum salmon in the Sheenjek River, 1981-2008.

Year	Starting Date	Ending Date	Project Duration	Sonar Estimate	Expanded Estimate
1981	31 Aug	24 Sep	25	74,560	
1982	31 Aug	22 Sep	23	31,421	
1983	29 Aug	24 Sep	27	49,392	
1984	30 Aug	25 Sep	27	27,130	
1985 [a]	02 Sep	29 Sep	28	152,768	
1986 [a]	17 Aug	24 Sep	39	83,197 [b]	84,207
1987 [a]	25 Aug	24 Sep	31	140,086	153,267
1988	21 Aug	27 Sep	38	40,866	45,206
1989	24 Aug	25 Sep	33	79,116	99,116
1990	22 Aug	28 Sep	38	62,200	77,750
1991	09 Aug	24 Sep	47	86,496	
1992	09 Aug	20 Sep	43	78,808	
1993	08 Aug	28 Sep	52	42,922	
1994	07 Aug	28 Sep	53	150,565	
1995	10 Aug	25 Sep	47	241,855	
1996	30 Jul	24 Sep	57	246,889	
1997	09 Aug	23 Sep	46	80,423	
1998	17 Aug	30 Sep	45	33,058	
1999	10 Aug	23 Sep	45	14,229	
2000	08 Aug	12 Sep	36	18,652 [c]	30,084
2001	11 Aug	23 Sep	44	53,932	
2002	09 Aug	24 Sep	47	31,642	
2003	09 Aug	26 Sep	49	38,321 [d]	44,047
2004	08 Aug	25 Sep	49	37,878	
2005 [a]	10 Aug	24 Sep	46	438,253 [d]	561,863
2006 [a]	09 Aug	24 Sep	47	160,178	
2007 [a]	11 Aug	24 Sep	45	65,435	
2008 [a]	09 Aug	24 Sep	47	42,842 [e]	50,353
1981-07	15 Aug	24 Sep	41	94,825	102,042
2002-07	09 Aug	24 Sep	47	148,013	172,735

[a] Sonar estimate is based on counts from both right and left bank sonar operations, all other years are right bank estimates only.

[b] Sonar–estimated escapement in these years was subsequently expanded to include fish passing prior to sonar operations (Barton 1995). Expansions for 1986–1988 and 1990 were based upon run timing data collected in the nearby Chandalar River. The 1989 estimate was expanded based upon aerial survey observations made in the Sheenjek River prior to sonar operations in that year.

[c] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated (Barton 2002). Expansions for 2000 were based upon average run time data from the Sheenjek River 1986–1999.

[d] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansions for 2003 and 2005 were based upon run time data from the Rampart Rapids tag recovery fish wheel (Dunbar 2006, Dunbar 2009).

[e] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansion was based upon run time data from the Rampart Rapids tag recovery fish wheel (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication).

Table 2.–Sonar-estimated passage of fall chum salmon in the Sheenjek River, 2008.

	Daily			Cumulative			% of Total
Date	Right Bank	Left Bank	Total	Right Bank	Left Bank	Total	Passage
8/09 [a]	64	32	96	64	32	96	0.00
8/10	75	41	116	139	73	212	0.00
8/11	41	58	99	180	131	311	0.01
8/12	28	66	94	208	197	405	0.01
8/13	40	79	119	248	276	524	0.01
8/14	54	62	116	302	338	640	0.01
8/15	51	65	116	353	403	756	0.02
8/16	77	61	138	430	464	894	0.02
8/17	68	70	138	498	534	1,032	0.02
8/18	49	76	125	547	610	1,157	0.03
8/19	65	65	130	612	675	1,287	0.03
8/20	88	41	129	700	716	1,416	0.03
8/21	71	41	112	771	757	1,528	0.04
8/22	70	29	99	841	786	1,627	0.04
8/23	59	65	124	900	851	1,751	0.04
8/24	76	59	135	976	910	1,886	0.04
8/25	93	57	150	1,069	967	2,036	0.05
8/26	94	53	147	1,163	1,020	2,183	0.05
8/27	156	57	213	1,319	1,077	2,396	0.06
8/28	162	77	239	1,481	1,154	2,635	0.06
8/29	327	118	445	1,808	1,272	3,080	0.07
8/30	402	98	500	2,210	1,370	3,580	0.08
8/31	644	144	788	2,854	1,514	4,368	0.10
9/01	1,034	167	1,201	3,888	1,681	5,569	0.13
9/02	841	149	990	4,729	1,830	6,559	0.15
9/03	1,536	365	1,901	6,265	2,195	8,460	0.20
9/04	1,876	437	2,313	8,141	2,632	10,773	0.25 [b]
9/05	1,609	534	2,143	9,750	3,166	12,916	0.30
9/06	1,501	462	1,963	11,251	3,628	14,879	0.35
9/07	1,597	379	1,976	12,848	4,007	16,855	0.39
9/08	1,564	294	1,858	14,412	4,301	18,713	0.44
9/09	994	270	1,264	15,406	4,571	19,977	0.47
9/10	966	260	1,226	16,372	4,831	21,203	0.49
9/11	1,163	168	1,331	17,535	4,999	22,534	**0.53** [c]
9/12	1,576	170	1,746	19,111	5,169	24,280	0.57
9/13	1,269	166	1,435	20,380	5,335	25,715	0.60
9/14	1,081	108	1,189	21,461	5,443	26,904	0.63
9/15	671	62	733	22,132	5,505	27,637	0.65
9/16	506	47	553	22,638	5,552	28,190	0.66
9/17	1,248	61	1,309	23,886	5,613	29,499	0.69
9/18	1,658	155	1,813	25,544	5,768	31,312	0.73
9/19	2,000	151	2,151	27,544	5,919	33,463	0.78
9/20	2,104	215	2,319	29,648	6,134	35,782	0.84
9/21	1,596	278	1,874	31,244	6,412	37,656	0.88
9/22	1,366	214	1,580	32,610	6,626	39,236	0.92
9/23	1,752	190	1,942	34,362	6,816	41,178	0.96
9/24 [d]	1,550	114	1,664	35,912	6,930	42,842	1.00

[a] Both right and left bank operational.
[b] Single boxed area identifies central half of the observed run.
[c] Bold box identifies the observed mid-point.
[d] Last day of sonar operation.

Table 3.–Number of minutes by bank that were either expanded or interpolated to calculate the hourly or daily estimate, 2008.

Date	Right Bank	Left Bank
8/09	450	829
8/10	4	23
8/11	280	307
8/12		19
8/13		
8/14		
8/15		
8/16		
8/17		
8/18		
8/19		
8/20		
8/21		
8/22	20	
8/23		
8/24		
8/25		
8/26		
8/27		
8/28		
8/29		
8/30		
8/31		
9/01		
9/02		
9/03		
9/04	38	36
9/05		
9/06		
9/07		
9/08		164
9/09		
9/10		
9/11		
9/12		
9/13		
9/14		
9/15	16	
9/16		130
9/17		
9/18	7	
9/19		
9/20		
9/21		
9/22		
9/23		
9/24		
Total	815	1508

Table 4.–Postseason daily expansion.

Day	Date	Daily Expansion
1	9/25	1,450
2	9/26	1,251
3	9/27	1,066
4	9/28	895
5	9/29	740
6	9/30	599
7	10/1	474
8	10/2	363
9	10/3	266
10	10/4	185
11	10/5	118
12	10/6	67
13	10/7	30
14	10/8	7
15	10/9	0
Sum		7,511
Sonar Estimate Through 9/24		42,842
Total Season Estimate		50,353

Table 5.–Sheenjek River test fishing (beach seine) results, 2008.

Date	Number of Sets	Location (rkm)[a]	Chum Salmon Captured Male	Chum Salmon Captured Female	Chum Salmon Captured Total	Arctic Grayling	Northern Pike	Round Whitefish	Burbot
9/02	3	10	0	0	0	0	0	0	0
9/03	3	10	1	0	1	0	1	0	0
9/04	4	9	0	1	1	0	0	0	0
9/05	6	9	0	0	0	0	0	0	0
9/06	7	9, 10	4	2	6	1	0	0	1
9/08	4	10	3	0	3	1	0	0	0
9/09	4	10	6	10	16	0	1	0	0
9/11	6	10	8	4	12	3	1	0	0
9/12	3	10	7	8	15	0	0	0	0
9/14	4	10	3	1	4	3	0	0	0
9/15	4	10	9	9	18	3	2	1	0
9/17	4	10	8	0	8	2	0	0	0
9/18	4	10	5	3	8	6	0	0	0
9/20	4	10	6	5	11	14	2	0	0
9/22	4	10	6	8	14	7	0	0	0
Total	64		66 (56%)	51 (44%)	117	40	7	1	1

[a] Locations are river kilometer (rkm). The sonar site is at rkm 10.

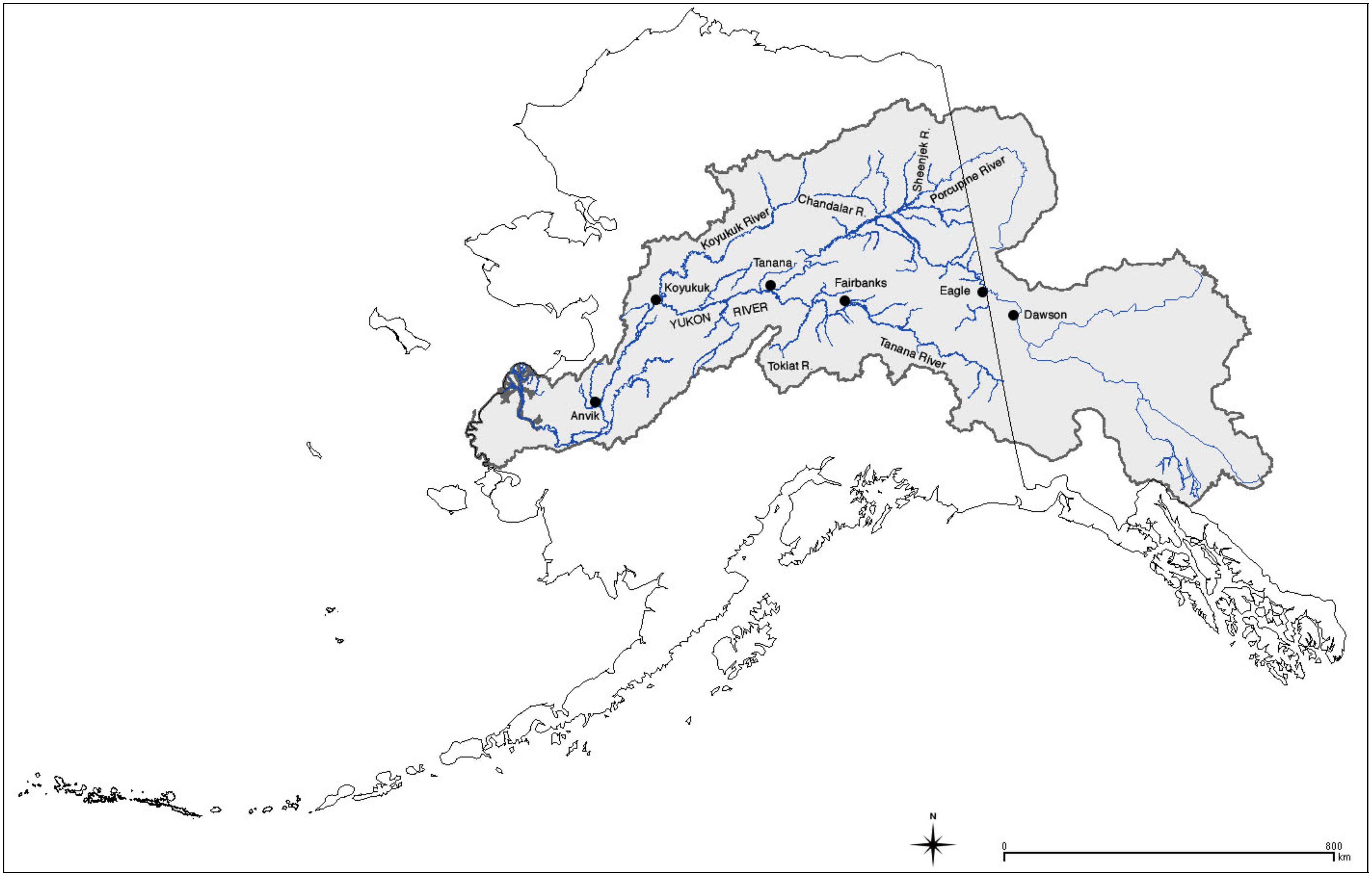

Figure 1.–The Yukon River drainage showing selected locations.

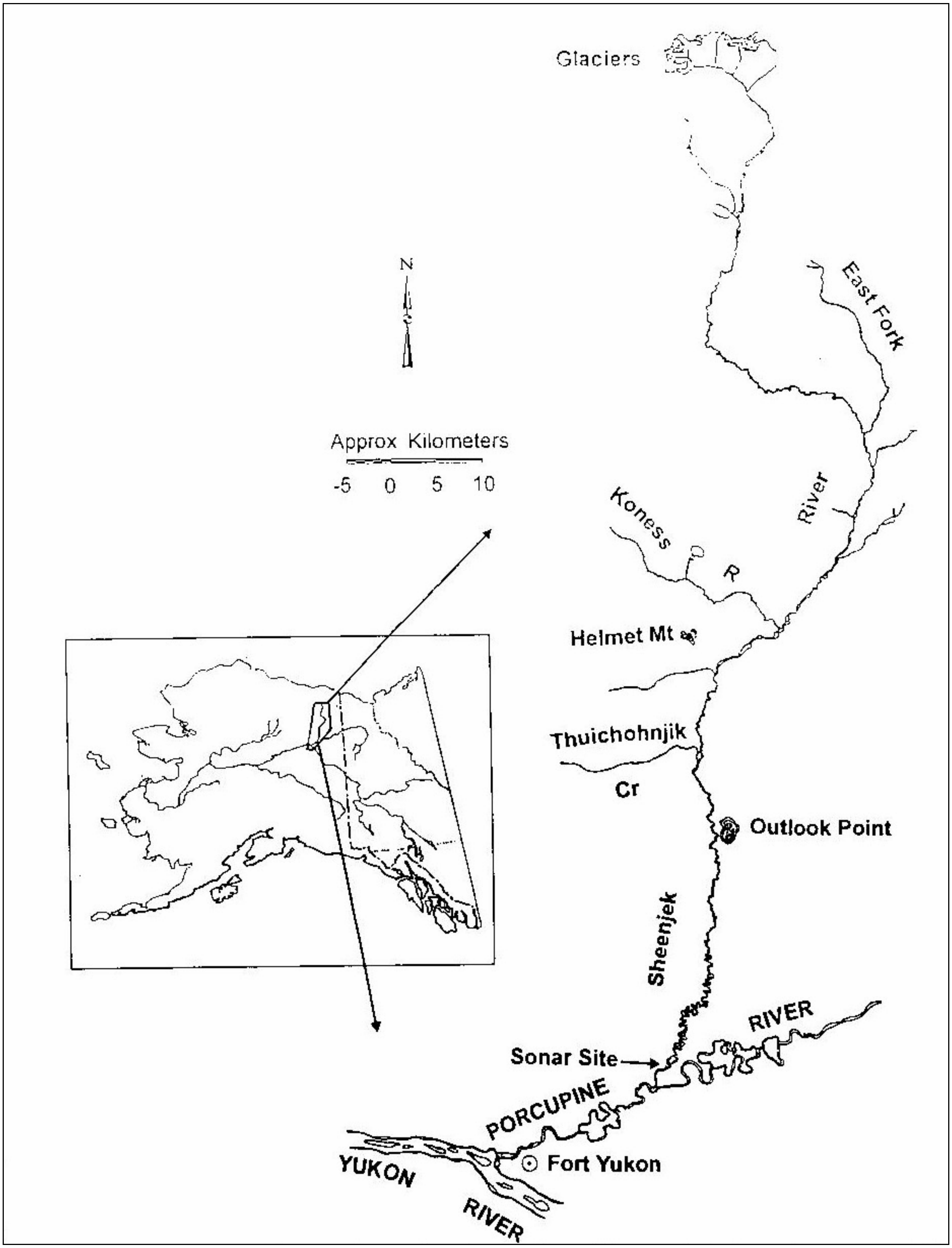

Figure 2.–The Sheenjek River drainage.

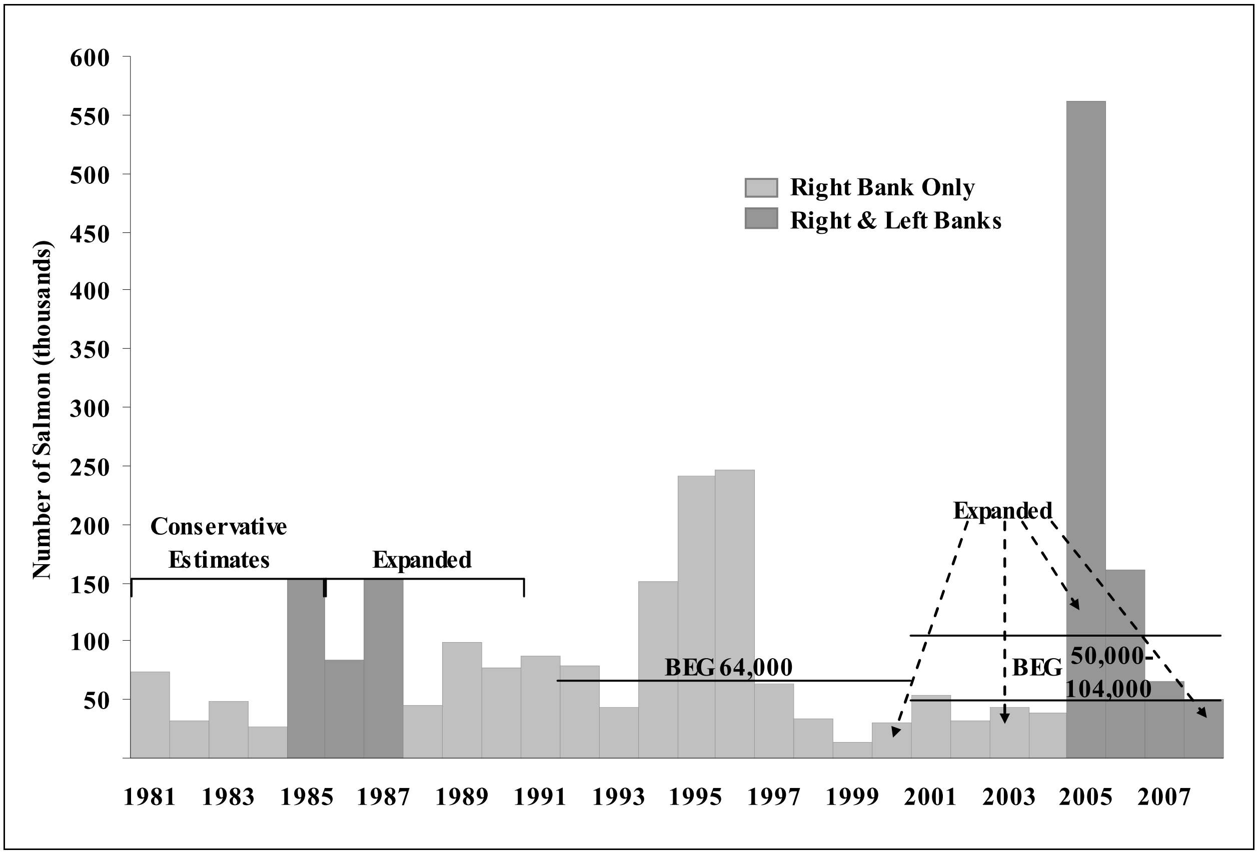

Figure 3.–Sonar-estimated escapement and BEG (horizontal lines) of fall chum salmon in the Sheenjek River, 1981–2008. Although the total escapement estimates for 2007 and 2008 were greater than the low end of the current BEG, the BEG was not achieved because it was based on right bank estimates only.

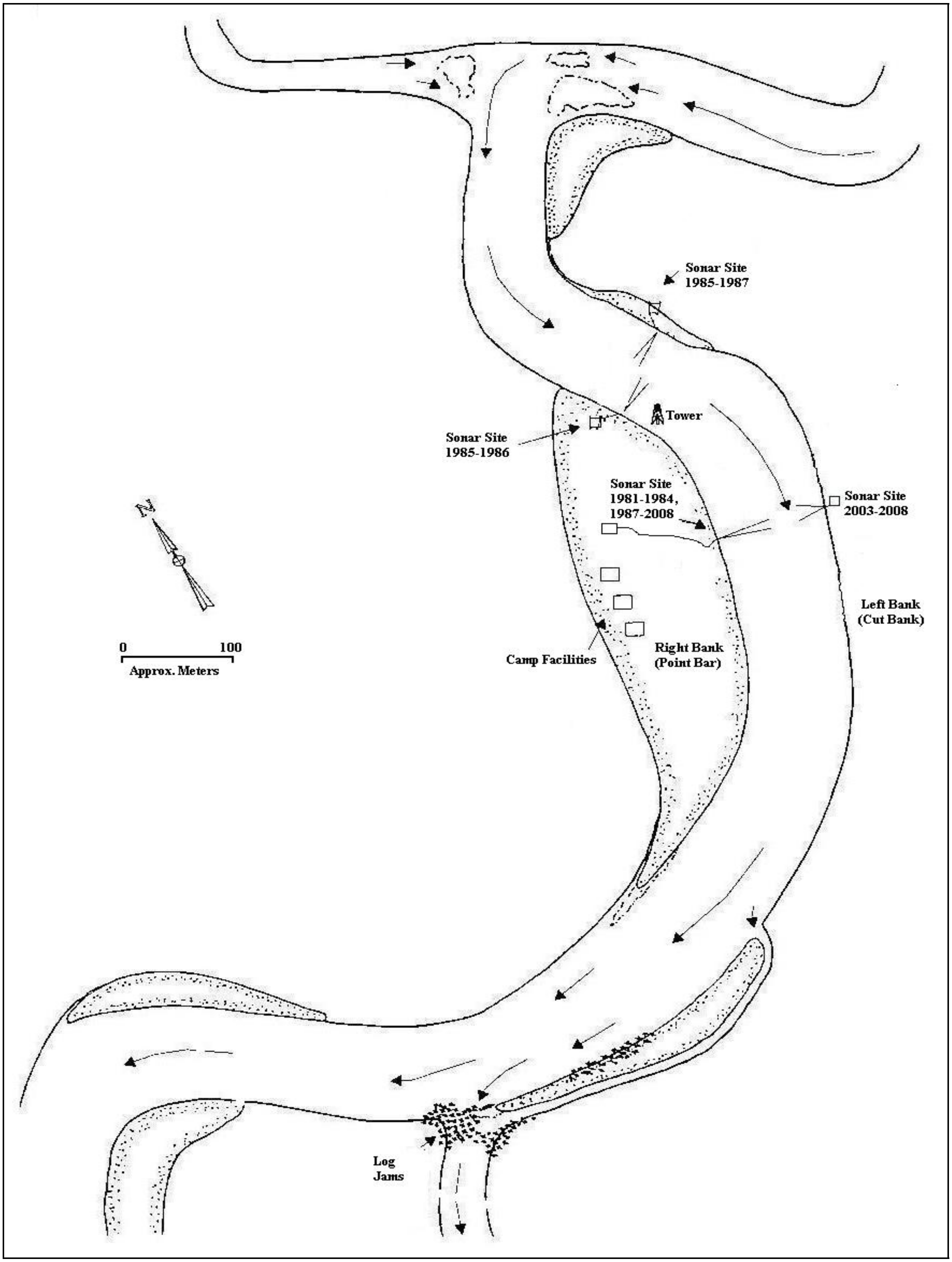

Figure 4.–The Sheenjek River sonar project site.

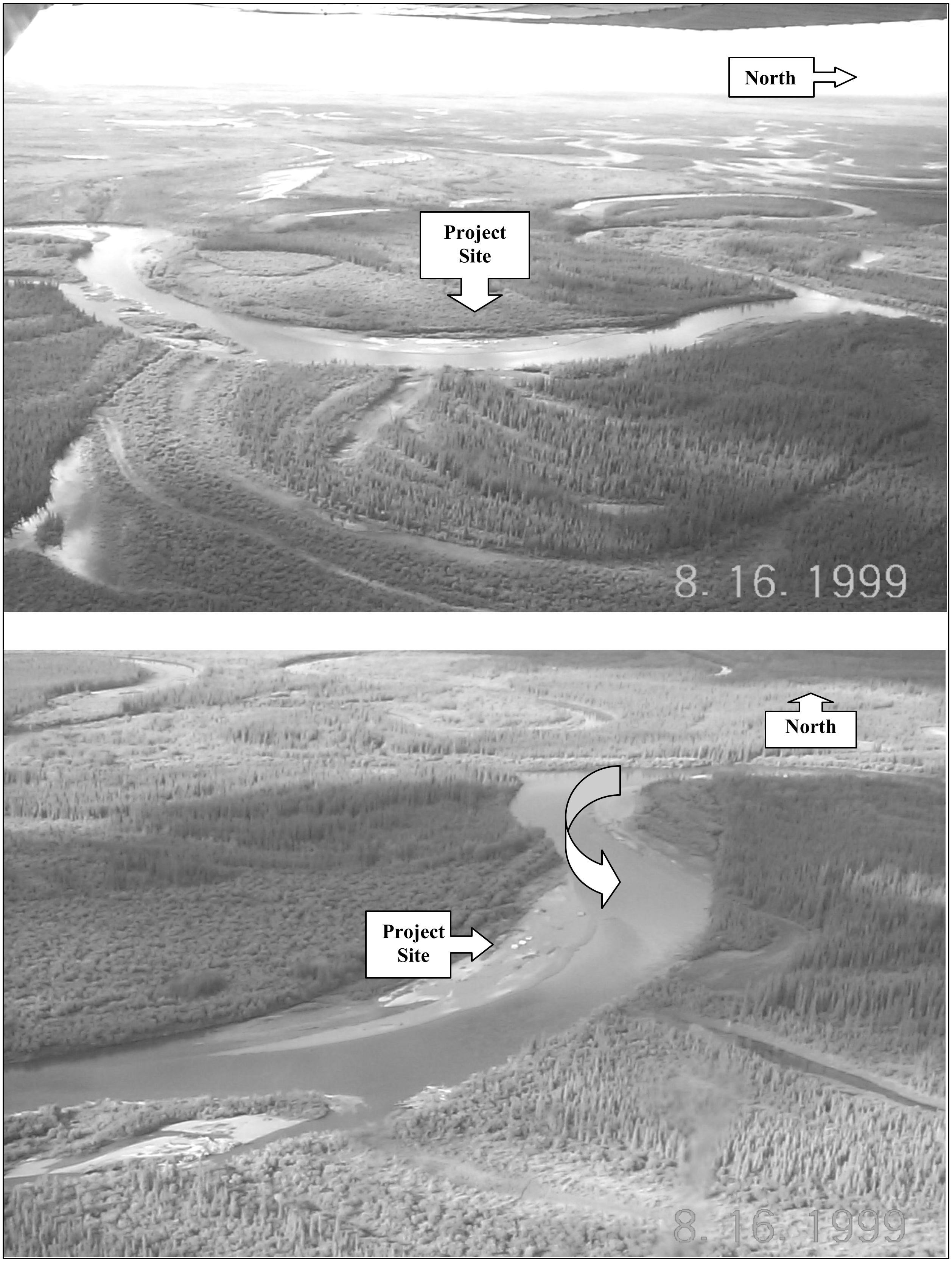

Figure 5.–Aerial photographs of the Sheenjek River sonar project site taken August 16, 1999.

Figure 6.–DIDSON attached to H-style mount with manual rotator prior to deployment.

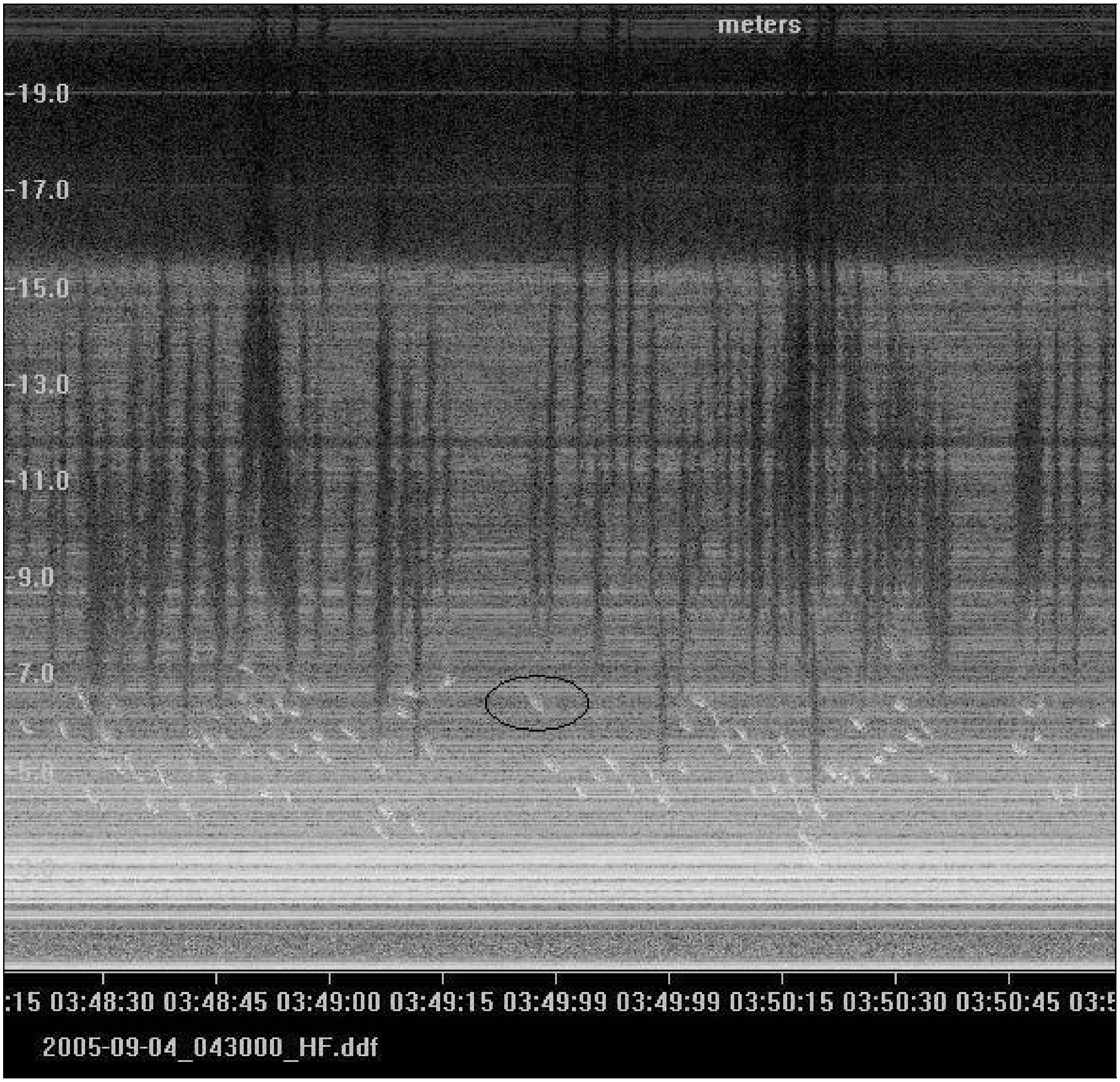

Figure 7.–Screenshot of DIDSON echogram with oval around representative fish.

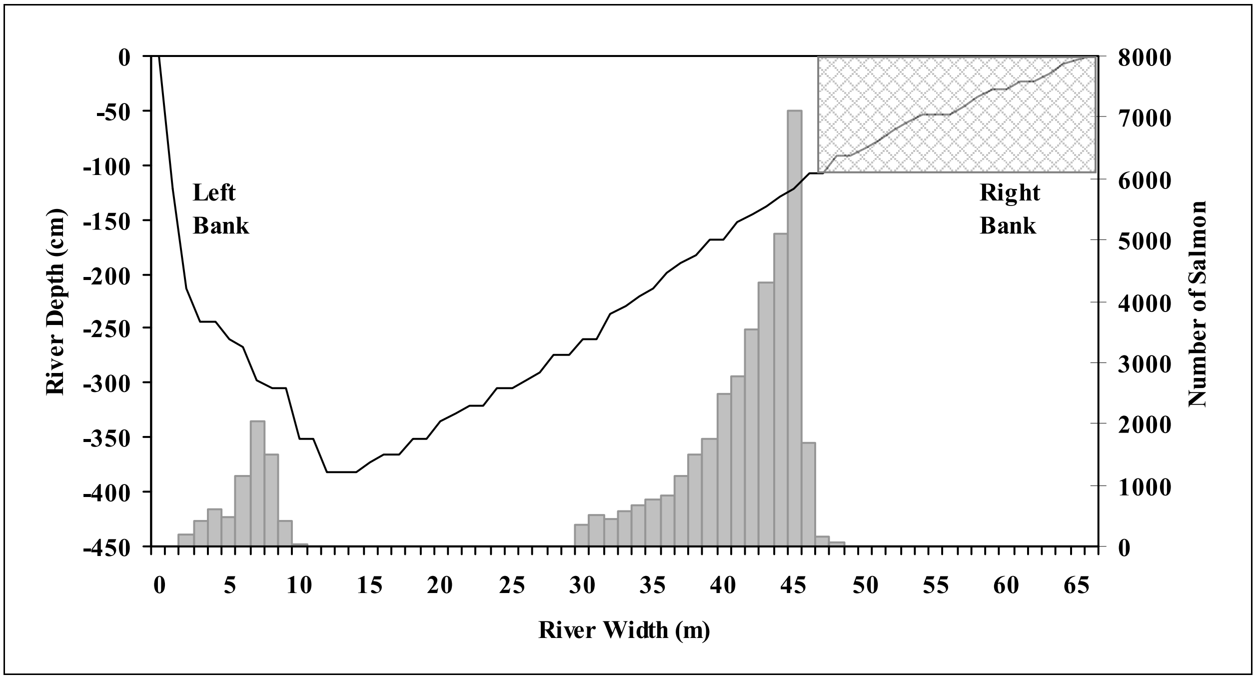

Figure 8.–Depth profile (downstream view) made August 14, at the project site. Cross hatch represents portion of river blocked by fish lead and vertical bars represent horizontal distribution of upstream fall chum salmon passage through ensonified zone of the Sheenjek River, 2008.

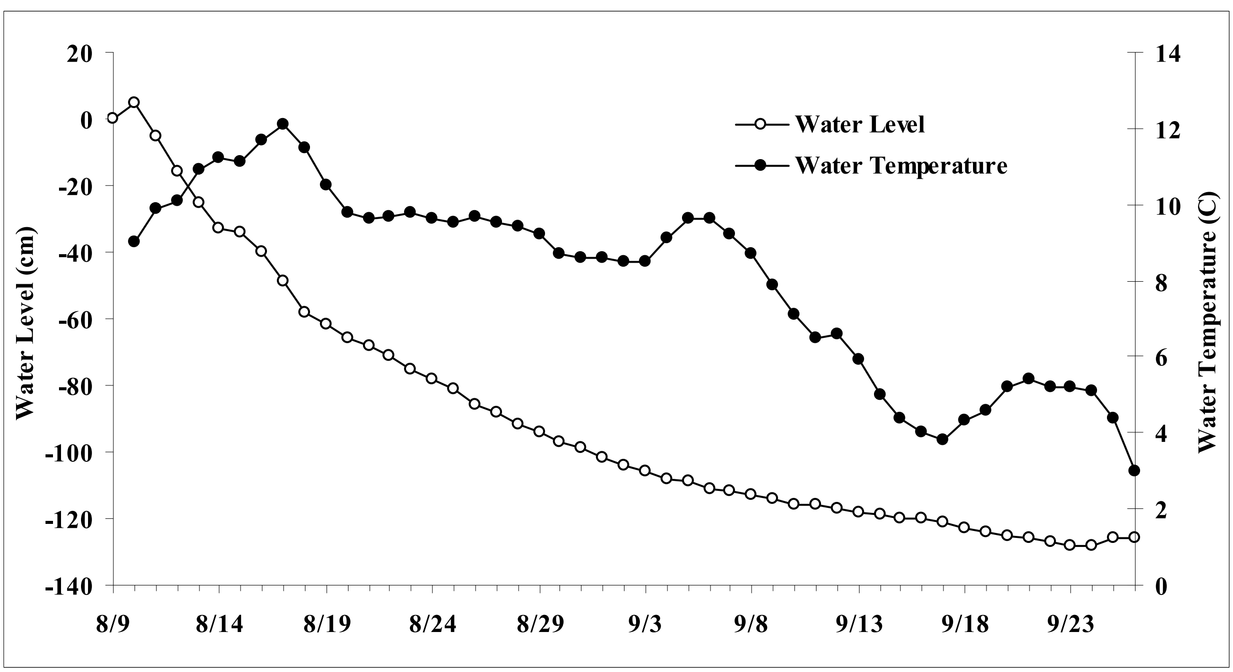

Figure 9.–Changes in daily water level relative to August 9, and water temperature measured at the Sheenjek River sonar project site, 2008.

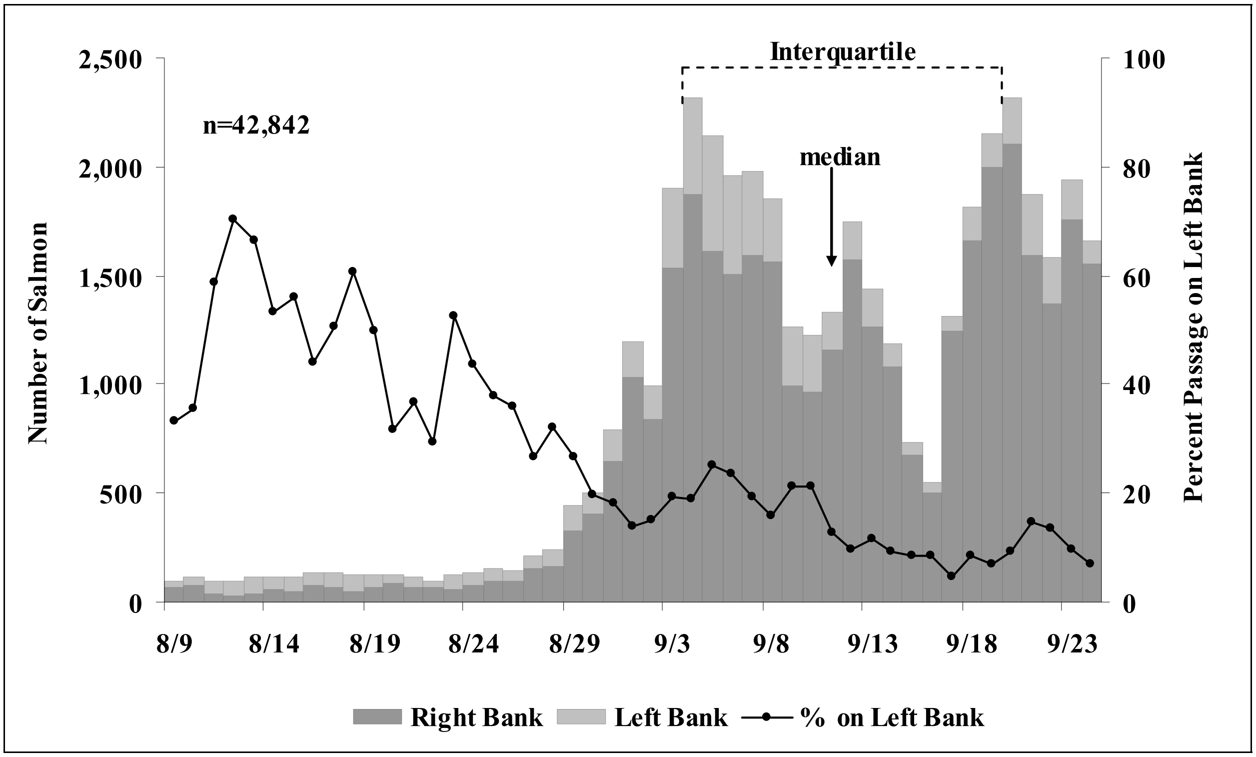

Figure 10.–Fall chum salmon sonar counts by day, and percentage of passage on the left bank at Sheenjek River sonar site, August 11 through September 24, 2008.

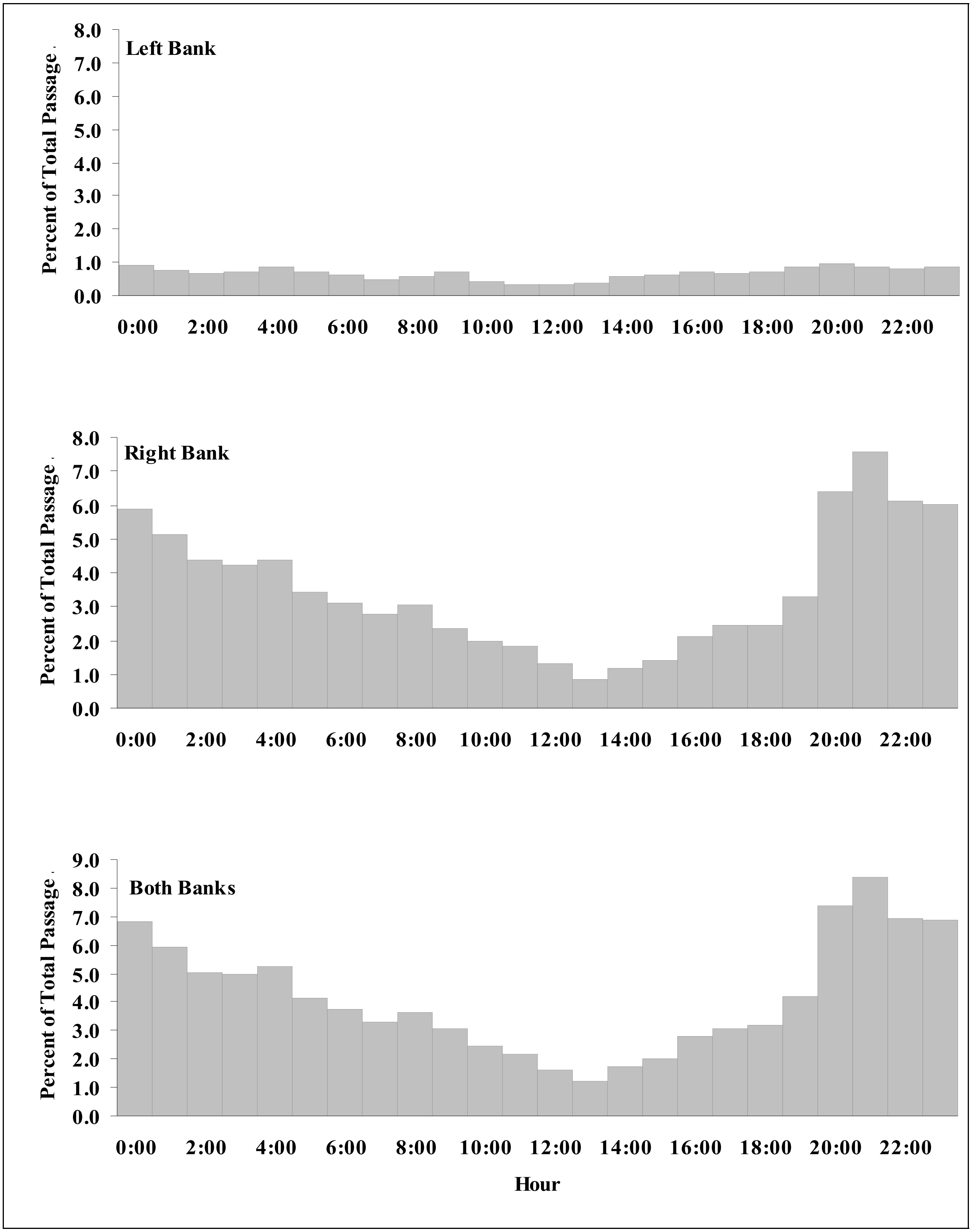

Figure 11.–Diel migration pattern of fall chum salmon on the left bank (top), right bank (middle), and both banks combined (bottom) of the Sheenjek River, from August 12 through September 24, 2008.

APPENDIX A. HARVEST OF YUKON RIVER FALL CHUM SALMON

Appendix A1.–Alaskan and Canadian total harvest of Yukon River fall chum salmon, 1970–2008.

Year	Canada [a]	Alaska [b,c]	Total
1970	3,711	265,096	268,807
1971	16,911	246,756	263,667
1972	7,532	188,178	195,710
1973	10,135	285,760	295,895
1974	11,646	383,552	395,198
1975	20,600	361,600	382,200
1976	5,200	228,717	233,917
1977	12,479	340,757	353,236
1978	9,566	331,250	340,816
1979	22,084	593,293	615,377
1980	22,218	466,087	488,305
1981	22,281	654,976	677,257
1982	16,091	357,084	373,175
1983	29,490	495,526	525,016
1984	29,267	383,055	412,322
1985	41,265	474,216	515,481
1986	14,543	303,485	318,028
1987	44,480	361,663 [d]	406,143
1988	33,565	319,677	353,242
1989	23,020	518,157	541,177
1990	33,622	316,478	350,100
1991	35,418	403,678	439,096
1992	20,815	128,031 [e]	148,846
1993	14,090	76,925 [d]	91,015
1994	38,008	131,217	169,225
1995	45,600	415,547	461,147
1996	24,354	236,569	260,923
1997	15,580	154,479 [e]	170,059
1998	7,951	62,869 [d]	70,820
1999	19,636	110,369	130,005
2000	9,236	19,307 [d]	28,543
2001	9,822	35,154 [d]	44,976
2002	8,018	19,393 [d]	27,411
2003	11,355	68,174	79,529
2004	9,750	66,546	76,296
2005	18,337	271,846	290,183
2006	11,796	258,342	270,138
2007	13,830	189,390	203,220
2008 [f]	9,566	199,284	208,850
Average			
1970-07	19,561	276,926	296,487
1998-07	11,973	110,139	122,112
2003-07	13,014	170,860	183,873

Source: Modified from JTC 2009.

[a] Catch in number of salmon. Includes commercial, Aboriginal, domestic and sport catches combined.

[b] Catch in number of salmon. Includes estimated number of salmon harvested for commercial production of salmon roe.

[c] Commercial, subsistence, personal-use and ADF&G test fish catches combined.

[d] Commercial fishery did not operate in Alaskan portion of drainage.

[e] Commercial fishery operated only in District 6 (Tanana River).

[f] Data are preliminary.

APPENDIX B. CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climate and hydrologic observations at the Sheenjek River project site, 2008.

					Temperature (C°)			Water Level (cm)		
		Cloud	Wind			Air				Water
	Precipitation	Cover			Water			± 24 h	Relative to	Color
Date	(code)[a]	(code)[b]	Direction	Velocity (mph)	Surface[c]	Minimum	Maximum	Change	Zero Datum	(code)[d]
8/09	A	B	NE	5	ND	ND	ND	zero datum	0	B
8/10	B	B	SSE	1	9.0	ND	ND	5	5	B
8/11	A	S	SW	2	9.9	2	25	-10	-5	B
8/12	A	S	ESE	10	10.1	2	21	-11	-16	A
8/13	A	B	ESE	15	10.9	10	20	-9	-25	A
8/14	A	O	SE	8	11.2	10	18	-8	-33	A
8/15	A	O	SW	1	11.1	10	20	-1	-34	A
8/16	A	S	ESE	6	11.7	ND	ND	-6	-40	A
8/17	A	S	ENE	13	12.1	7	23	-9	-49	A
8/18	A	C	NE	7	11.5	4	19	-9	-58	A
8/19	A	C	ENE	8	10.5	2	18	-4	-62	A
8/20	A	C	ENE	8	9.8	2	20	-4	-66	A
8/21	A	S	NE	9	9.6	3	20	-2	-68	A
8/22	A	S	ENE	3	9.7	4	18	-3	-71	A
8/23	A	C	NE	5	9.8	4	ND	-4	-75	A
8/24	A	C	ENE	15	9.6	3	16	-3	-78	A
8/25	A	B		0	9.5	2	20	-3	-81	A
8/26	A	C	E	5	9.7	3	19	-5	-86	A
8/27	A	B	NNE	9	9.5	4	15	-2	-88	A
8/28	A	C	NE	2	9.4	3	16	-4	-92	A
8/29	A	C		0	9.2	0	18	-2	-94	A
8/30	A	C	SW	1	8.7	-2	19	-3	-97	A
8/31	A	C	ENE	3	8.6	-2	18	-2	-99	A
9/01	A	C	NE	5	8.6	4	19	-3	-102	A
9/02	A	C	NNE	1	8.5	4	18	-2	-104	A
9/03	A	S	ENE	2	8.5	4	21	-2	-106	A
9/04	A	B		0	9.1	10	22	-2	-108	A
9/05	A	S	WSW	1	9.6	7	22	-1	-109	A
9/06	A	S		0	9.6	1	20	-2	-111	A

-continued-

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			Wind		Temperature (C°)			Water Level (cm)		
					Water	Air				Water
Date	Precipitation (code)[a]	Cloud Cover (code)[b]	Direction	Velocity (mph)	Surface[c]	Minimum	Maximum	± 24 h Change	Relative to Zero Datum	Color (code)[d]
9/07	A	O	NE	7	9.2	4	18	-1	-112	A
9/08	A	B		0	8.7	5	15	-1	-113	A
9/09	A	S	NE	5	7.9	-2	15	-1	-114	A
9/10	A	O	NNE	4	7.1	2	10	-2	-116	A
9/11	A	B	SSW	4	6.5	-4	13	0	-116	A
9/12	A	S	NE	6	6.6	3	11	-1	-117	A
9/13	A	C	NE	7	5.9	-2	9	-1	-118	A
9/14	A	B	NE	13	5.0	-2	8	-1	-119	A
9/15	A	S		0	4.4	-1	8	-1	-120	A
9/16	A	S	NE	10	4.0	-4	9	0	-120	A
9/17	B	O	NE	5	3.8	2	8	-1	-121	A
9/18	A	O	NE	7	4.3	2	10	-2	-123	A
9/19	A	B	NE	8	4.6	1	14	-1	-124	A
9/20	A	B	WSW	6	5.2	5	11	-1	-125	A
9/21	A	C	W	8	5.4	2	11	-1	-126	A
9/22	A	C	WSW	2	5.2	-1	10	-1	-127	A
9/23	A	B		0	5.2	-3	11	-1	-128	A
9/24	A	C	NE	10	5.1	0	8	0	-128	A
9/25	A	C	NNE	11	4.4	-2	6	2	-126	A
9/26	A	S		0	3.0	-7	5	0	-126	A
9/27	E	O	NNE	5	ND	-9	0	ND	ND	A
Average					7.4	2	15			

[a] Precipitation code for the preceding 24-hr period: A = None; B = Intermittent rain; C = Continuous rain; D = snow and rain mixed; E = light snowfall; F = Continuous snowfall; G = Thunderstorm w/ or w/o precipitation.

[b] Cloud cover code: C = Ceiling and visibility unlimited (CAVU); S = Scattered (<60%); B = Broken (60-90%); O = Overcast (100%); F = Fog or thick haze or smoke.

[c] Water temperature collected 30 cm below surface with HOBO data logger 8/13-9/24, and pocket thermometer all other dates.

[d] Water color code: A = Clear; B = Slightly murky or glacial; C = Moderately murky or glacial; D = Heavily murky or glacial; E = Brown, tannic acid stain.

APPENDIX C. AGE COMPOSITION ESTIMATES

Appendix C1.–Age composition estimates of Sheenjek River fall chum salmon, 1974–2008.

Year[a]	Sample (readable)	Age 0.2	0.3	0.4	0.5	Estimated Escapement
1974 [b]	136	0.669	0.301	0.029	0.000	89,966
1975 [b]	197	0.036	0.949	0.015	0.000	173,371
1976 [b]	118	0.017	0.441	0.542	0.000	26,354
1977 [b]	178	0.112	0.725	0.163	0.000	45,544
1978 [b]	190	0.079	0.821	0.100	0.000	32,449
1979	ND					91,372
1980	ND					28,933
1981 [c]	340	0.029	0.850	0.118	0.003	74,560
1982 [c]	109	0.030	0.470	0.490	0.010	31,421
1983 [c]	108	0.065	0.870	0.065	0.000	49,392
1984 [d]	297	0.101	0.805	0.094	0.000	27,130
1985 [d]	508	0.012	0.927	0.061	0.000	152,768
1986 [d]	442	0.081	0.412	0.500	0.007	84,207
1987 [d]	431	0.021	0.898	0.072	0.009	153,267
1988 [d,e]	120	0.025	0.683	0.292	0.000	45,206
1989 [d,e]	154	0.052	0.766	0.169	0.013	99,116
1990 [d]	143	0.028	0.706	0.252	0.014	77,750
1991 [d]	147	0.000	0.592	0.395	0.014	86,496
1992 [d]	134	0.000	0.179	0.806	0.015	78,808
1993 [d,e]	192	0.005	0.640	0.339	0.016	42,922
1994 [d]	173	0.012	0.561	0.405	0.023	153,000
1995 [d]	166	0.012	0.542	0.386	0.060	235,000
1996 [d]	191	0.016	0.330	0.618	0.037	248,000
1997	ND					80,423
1998	3					33,058
1999	ND					14,229
2000	ND					30,084
2001 [f]	71	0.000	0.352	0.648	0.000	53,932
2002 [g]	31	0.000	0.613	0.387	0.000	31,642
2003 [d]	84	0.012	0.821	0.155	0.012	44,047
2004 [d]	104	0.115	0.615	0.250	0.019	37,878
2005 [d]	194	0.000	0.923	0.067	0.010	561,863
2006 [d,h]	179	0.012	0.229	0.732	0.028	160,178
2007 [d]	76	0.000	0.526	0.355	0.118	65,435
2008 [d]	116	0.090	0.431	0.517	0.350	42,842
	Avg 1974-07	0.055	0.627	0.304	0.015	95,288
	Avg 1998-07	0.020	0.583	0.371	0.027	103,235
	Even Years	0.085	0.512	0.393	0.011	71,533
	Odd years	0.025	0.742	0.215	0.018	119,043

[a] Age determination from scales for years 1974–1985; and from vertebrae since 1986.
[b] Carcass samples from spawning grounds.
[c] Escapement samples taken with 5-7/8 inch gillnets at rkm 10.
[d] Escapement samples taken with beach seine rkm 5–20.
[e] Escapement samples were predominantly taken late in run.
[f] 68 carcass samples and 5 beach seine samples collected between rkm 11 and 25.
[g] 30 beach seine samples collected at rkm 13 and 1 carcass collected at rkm 10.
[h] 14 carcass samples collected between rkm 10 and 35.